CLAIMS

1. An apparatus for producing gas atom containing fullerenes comprising a plasma generating chamber with a gas inlet where a gas to be doped is introduced via the gas inlet into said chamber to be converted into a plasma there, and an evacuated vessel which is so constructed as to communicate with the plasma generating chamber to produce a plasma flow and to introduce fullerenes into the plasma flow such that at least part of the fullerenes are ionized, said apparatus being further provided with means for binding ionized atom to be doped to fullerenes thereby causing endohedral fullerens to be formed.

2. The apparatus for producing gas atom containing fullerenes as described in Claim 1 wherein the gas comprises atom to be doped which is ionized in plasma to provide electrons and positively charged ions to be doped.

3. The apparatus for producing gas atom containing fullerenes as described in Claim 2 wherein means for controlling the energy of electrons in plasma flow is provided in the evacuated vessel towards the plasma generating chamber, and wherein the energy controls the energy of electrons to facilitate the binding of the electrons to fullerenes introduced into the evacuated chamber thereby causing negatively charged fullerene ions to be formed.

4. The apparatus for producing gas atom containing

fullerenes as described in Claim 3 wherein the energy of the electrons is controlled to be 10 eV or lower.

5. The apparatus for producing gas atom containing fullerenes as described in Claim 3 wherein the energy of the electrons is controlled to be 5 eV or lower.

6. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 2 to 5 wherein the atom to be doped comprises hydrogen atom or nitrogen atom.

7. The apparatus for producing gas atom containing fullerenes as described in Claim 1 wherein the gas comprises atom to be doped which is ionized in plasma to provide negatively charged ions to be doped.

8. The apparatus for producing gas atom containing fullerenes as described in Claim 7 wherein fullerenes, when introduced into plasma flow, the electrons of fullerenes are expelled, to produce thereby positively charged fullerene ions.

9. The apparatus for producing gas atom containing fullerenes as described in Claim 7 or 8 wherein the atom to be doped comprises halogen gas atom.

10. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 1 to 9 wherein the means for binding ionized atom to be doped to fullerenes to cause thereby gas atom-doped fullerenes to be formed is a potential body to which a bias voltage having the same polarity with that of the atom to be doped is

applied.

11. The apparatus for producing gas atom containing fullerenes as described in Claim 10 wherein the potential body is divided into separate components in a radial direction.

12. The apparatus for producing gas atom containing fullerenes as described in Claim 11 constructed such that voltages different from each other can be applied to the separate components.

13. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 10 to 12 wherein the potential body is a substrate body.

14. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 10 to 12 wherein the potential body is a mesh body.

15. The apparatus for producing gas atom containing fullerenes as described in Claim 14 wherein a collecting container is provided downstream of the mesh body to collect produced endohedral fullerenes.

16. The apparatus for producing gas atom containing fullerenes as described in Claim 15 wherein the collecting container is freely attached to or detached from the apparatus.

17. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 1 to 16 wherein the plasma generating chamber is made of an insulating material, a coil is wound around its external

portion, and radiofrequency current is flowed through the coil.

18. The apparatus for producing gas atom containing fullerenes as described in Claim 17 wherein RF currents different in phase from each other are flowed through respective plural coils.

19. The apparatus for producing gas atom containing fullerenes as described in Claim 17 wherein a wire is wound spirally around one part of the external portion of the plasma generating chamber to form a first coil there, and another wire is wound spirally around another part of the external portion of the plasma generating chamber to form a second coil there, and RF currents different in phase are flowed through the first and second coils.

20. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 10 to 19 wherein the bias voltage is variable.

21. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 11 to 20 wherein a bias voltage $\Delta\phi ap$ in the range of $-100V < \Delta\phi ap < +100V$ is applied to the central component of the potential body.

22. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 11 to 21 wherein the radius of the central component is in the range of $R + 2R_L$ to $R + 3R_L$ where R represents the radius of the plasma generating chamber, and R_L the Larmor radius of a

doping atom.

23. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 10 to 22 wherein means for measuring the distribution of fullerene ions and doping atom ions in plasma flow is provided ahead the potential body, and the bias voltage applied to the potential body is adjusted based on a signal from said means.

24. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 1 to 23 wherein a cylinder having an inner diameter 2.5 to 3.0 times as large as the diameter of plasma flow is provided midway in the course of the plasma flow.

25. The apparatus for producing gas atom containing fullerenes as described in Claim 24 wherein the distance Id between the downstream end of the cylinder and the potential body is adjusted such that $Id \geqq 2Ic$ where Ic represents the length of the cylinder.

26. The apparatus for producing gas atom containing fullerenes as described in Claim 24 or 25 further comprising a cooling means for cooling at least the wall of the evacuated vessel surrounding the space downstream of the downstream end of the cylinder.

27. The apparatus for producing gas atom containing fullerenes as described in any one of Claims 1 to 26 wherein an inert membrane made mainly of chromium oxide is applied to the inner surfaces of the plasma generating

chamber and evacuated vessel.

28. A method for producing gas atom containing fullerenes using an apparatus as described in any one of Claims 1 to 27.

29. A method for producing gas atom containing fullerenes comprising the steps of introducing a gas containing atom to be doped into a plasma generating chamber, generating a plasma in the plasma generating chamber, causing the generated plasma to plasma flow, introducing fullerenes into the plasma flow thereby ionizing the fullerenes, and binding ions derived from the atom to be doped to ionized fullerenes thereby causing gas atom containing fullerenes to be formed.

30. The method for producing gas atom containing fullerenes according to Claim 29 wherein the gas comprises atom to be doped which is ionized in plasma to provide electrons and positively charged ions to be doped.

31. The method for producing gas atom containing fullerenes according to Claim 30 wherein the energy of electrons in plasma is controlled so as to facilitate the binding of electrons to fullerenes thereby causing negatively charged fullerenes to be formed.

32. The method for producing gas atom containing fullerenes according to Claim 31 wherein the energy of the electrons is controlled to be 10 eV or lower.

33. The method for producing gas atom containing fullerenes according to Claim 31 wherein the energy of the

electrons is controlled to be 5 eV or lower.

34. The method for producing gas atom containing fullerenes according to Claim 29 wherein the gas comprises atom to be doped which is ionized in plasma to provide negatively charged ions to be doped.

35. The method for producing gas atom containing fullerenes according to Claim 34 wherein fullerenes, when introduced into plasma flow, the electrons of fullerenes are expelled, to produce thereby positively charged fullerene ions.

36. The method for producing gas atom containing fullerenes according to any one of Claims 29 to 35 wherein the plasma generating chamber is made of an insulating material, a coil is wound around its external portion , and RF current is flowed through the coil.

37. The method for producing gas atom containing fullerenes according to Claim 36 wherein a pair of coils are wound spirally, and RF currents different in phase are flowed through the pair of coils.

38. The method for producing gas atom containing fullerenes according to Claim 36 wherein a wire is wound spirally around one part of the external portion of the plasma generating chamber to form a first coil there, and another wire is wound around spirally another part of the external portion of the plasma generating chamber to form a second coil there, and RF currents different in phase are flowed through the first and second coils.

39. The method for producing gas atom containing fullerenes according to any one of Claims 29 to 38 wherein the velocity of fullerenes relative to the velocity of ions derived from atom to be doped is reduced at the downstream side of plasma flow in the evacuated vessel.

40. The method for producing gas atom containing fullerenes according to Claim 39 wherein a potential body is provided in the evacuated vessel at a site which will correspond with the downstream side of plasma flow, and wherein, during operation, a bias voltage having the same polarity with that of doping ions in plasma is applied, thereby reducing the velocity of doping ions.

41. The method for producing gas atom containing fullerenes according to any one of Claims 29 to 40 wherein the concentration profile of fullerenes has a peak at the center of plasma flow.

42. The method for producing gas atom containing fullerenes according to Claim 40 wherein the potential body is divided into separate components in a radial direction, such that different voltages can be applied to the separate components independently of each other.

43. The method for producing gas atom containing fullerenes according to any one of Claims 40 to 42 wherein the potential body is a substrate body.

44. The method for producing gas atom containing fullerenes according to any one of Claims 40 to 42 wherein the potential body is a mesh body.

45. The method for producing gas atom containing fullerenes according to Claim 44 wherein a collecting container is provided downstream of the mesh body to collect produced endohedral fullerenes.

46. The method for producing gas atom containing fullerenes according to any one of Claims 29 to 45 wherein the initial vacuum of the evacuated vessel is 10^{-4} Pa or less.

47. A gas atom containing fullerene which is obtained by any one method chosen from those described in Claims 29 to 46.

48. A gas atom containing fullerene containing a hydrogen ion, a nitrogen ion or a halogen gas ion.

49. The gas atom containing fullerene as described in Claim 48 that has no modifying group attached thereto.

50. The gas atom containing fullerene as described in Claim 48 that has a modifying group attached thereto.

51. An electronic element including an electro-conductive polymer of any one gas atom containing fullerene chosen from those described in Claims 47 to 50.

52. The electronic element as described in Claim 51 which is a solar battery or a photo-sensor.